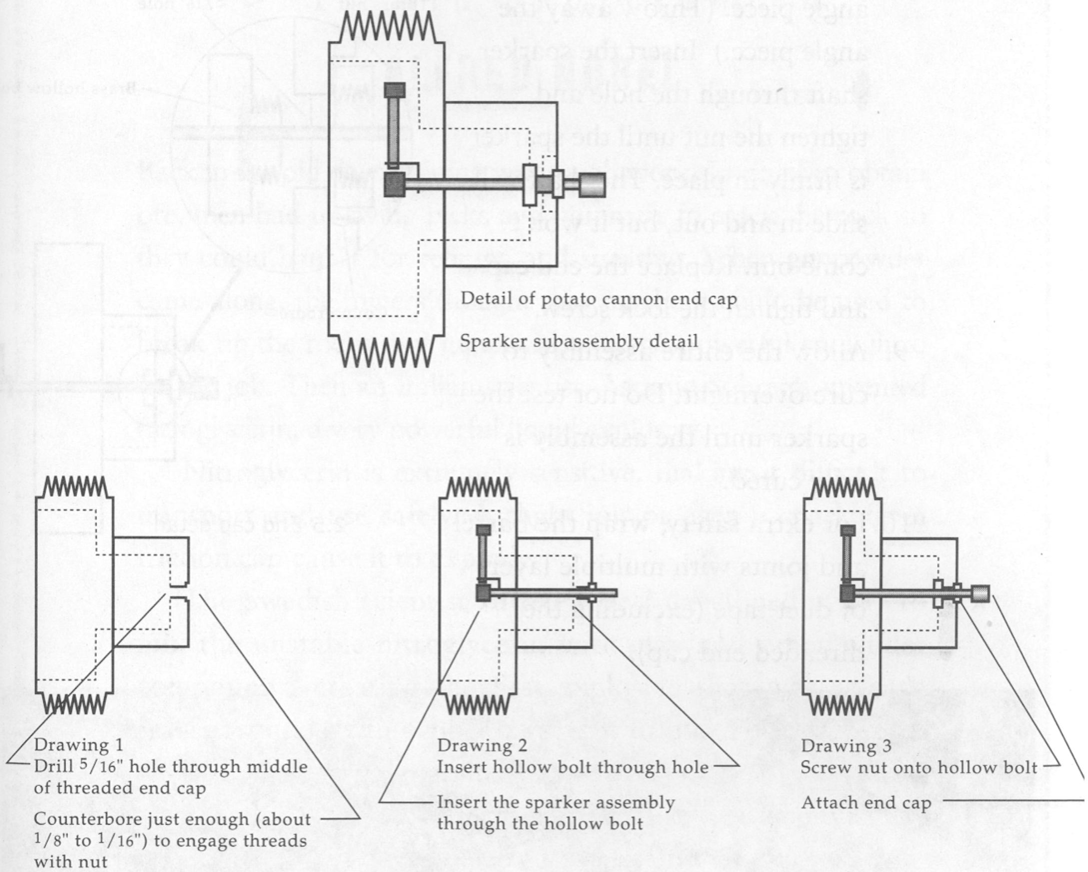
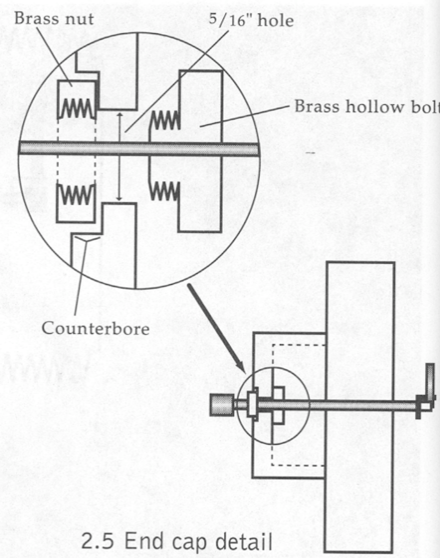


2.4 Detail for mounting sparker inside the end cap

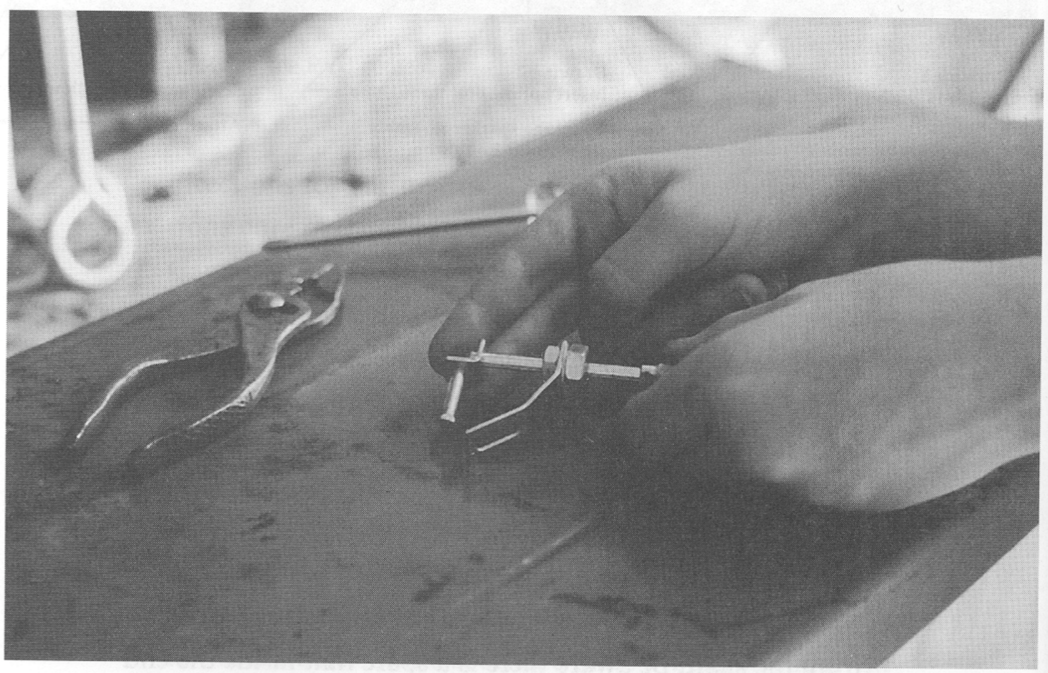
7. Take the hollow, threaded bolt assembly from the sparker and insert it through the hole made in step 6. Depending on the type of sparker you have, you may have to drill (counterbore) a ⅜-inch diameter depression on the outside surface of the end cap. Make it 1⁄16- to ⅛-inch deep in the PVC. You just need to reach and engage the hollow bolt's screw threads with the nut. (See diagram 2.5.)
8. Mount the sparker by unscrewing the knurled end cap from the shaft. Be aware there is a spare flint inside the end cap, so watch for it. Unscrew the nut and remove the metal

angle piece. (Throw away the angle piece.) Insert the sparker shaft through the hole and tighten the nut until the sparker is firmly in place. The shaft will slide in and out, but it won't come out. Replace the end cap and tighten the lock screw.

9. Allow the entire assembly to cure overnight. Do not test the sparker until the assembly is fully cured.
10. For extra safety, wrap the barrel and joints with multiple layers of duct tape (excluding the threaded end cap).



2.5 End cap detail



2.6 Sparker

KEEPING SAFETY IN MIND

1. The potato cannon shoots with enough force to cause injury. Always use extreme care when aiming the device. Make certain the end cap is fully screwed on.
2. The firing will cause a small recoil. You will need to mount the cannon securely to its firing platform.
3. Check the cannon after every use for signs of wear and to make sure the barrel maintains its structural integrity. Replace any worn sections or parts immediately.
4. Use only the type and quantity of propellant described. Do not use too much propellant or you may damage the cannon. Make certain the hairspray can is removed to a safe distance before the cannon is fired.
5. This device produces a loud noise. Use protective eyewear, hearing protection, and protective gloves.
6. Clear the area in front of the cannon for 200 yards. Clear the area behind the cannon for at least 25 yards.
7. Yell "Spuds away!" or "Fire in the hole!" before shooting to make sure no one's about to walk into the field of fire.

FIRING THE POTATO CANNON

It's finally time. Your cannon is ready, and you've studied the safety procedures. You've got a 10-pound bag of fresh Idaho russets, an economy-sized can of hairspray, and an itchy trigger finger. Let's march on out to the testing field and send those tubers into the stratosphere.

1. Remove the end cap.
2. Using the dowel or broom handle, ram a potato into the cannon from the muzzle end. The cutting edge made in step 1 of the assembly will cut the potato into a plug of

the correct size. The potato must fit snugly on all sides of the muzzle. Any gaps will allow the expanding gas to "blow by" the potato. If that happens, the potato plug won't go far.

3. Use the dowel to push the potato projectile 30 to 32 inches down into the cannon muzzle.
4. Direct a stream of hairspray into the firing chamber of the cannon (the 3-inch diameter cylinder where the sparker is mounted). It is important that you introduce the correct amount of hairspray into the combustion chamber. Because the amount of spray delivered per unit varies between spray cans, the correct amount of hairspray propellant is determined by trial and error. Start by using a very short burst of hairspray and increase the amount by small intervals until maximum performance is attained. *To reiterate*: Start with a very short burst and then try progressively larger amounts of hairspray. In general, a burst length of about two econds works well. *However*, the amount of hairspray actually delivered will vary among cans of hairspray. Therefore, start small and work up, but don't exceed two seconds.
5. Immediately replace the end cap and screw it on securely.
6. Twist the igniter sharply to fire the cannon.

TIPS AND TROUBLESHOOTING

1. A support, such as a ladder mount shown on page 20, is required to securely hold the cannon.
2. Use fresh potatoes. Old potatoes tend to mush or shred when rammed into the tapered muzzle. This results in the "blow by" effect described earlier.
3. Clean the spud gun after every few shots. Use the dowel

2.7 Using a ladder mount to secure the potato cannon

to push a wet rag through the muzzle to remove potato and hairspray residue.

4. **Note:** The threaded end cap often becomes difficult to remove after firing. Keep the threads scrupulously clean and always have a wrench handy in case it becomes stuck.

WHAT'S GOING ON HERE

You may be wondering just what is happening inside the cannon. Twisting the knob causes sparking inside the cannon's firing chamber. The sparks ignite the hairspray–air mixture inside. The gaseous mixture expands quickly and pushes against everything as it expands. The rigid PVC walls won't move, but the potato can, and does. In fact, the expanding gas moves so quickly and so rapidly that the potato flies out of the tube and into the air.

One can almost imagine Sir Isaac Newton, in a velvet waistcoat, breeches, and powdered wig, flicking the firing knob of a potato cannon. "I say," Newton would remark, "this proves my theories better than ye falling apples." Newton, of course, was a seventeenth-century English physicist and mathematician. He was also the fellow who came up with the concept of gravity while supposedly resting under an apple tree. In addition to his work on gravity and astronomy, Newton published a seminal book in terms of understanding the nature of motion. He titled it *Philosophiae Naturalis Principia Mathematica*. In *Principia*, he described three immutable physical laws that explain what are called the statics and dynamics of objects. Statics is the study of forces on an object at rest; dynamics is the study of how forces affect that object in motion.

You've probably heard of Isaac Newton's three laws of motion. These laws are the foundation of dynamics. The first law says that once something starts to move, it stays in motion until some force acts to stop it. This is often described as the principle of inertia. The second law says that if a force is exerted on an object, it goes faster, and the amount of force applied is proportional to the amount it accelerates. The final law states that every action has an equal and opposite reaction.

Our potato cannon illustrates parts of all three laws. The first law of motion tells us that after the potato is launched, it will continue to shoot forward until another force stops it. If the spud hits a tree, the opposing force is obvious. But if there is no tree in its way, why does the potato stop at all? Why doesn't the potato keep shooting forward forever? The potato stops moving only when the frictional force of the air and ground slow the potato and eventually stop it.

Let's go back to the example of a spud hitting a tree. We might wonder how much force the potato experiences when it thunks against the trunk. Well, according to Newton's second law, that thunk—the force of the potato—is equal to the mass of the potato multiplied by the acceleration of the potato. The spud gun imparts a big acceleration during the time the potato moves through the barrel of the cannon. So, when the potato decelerates from blasting through the air at high speed to an abrupt stop at the tree trunk, that's one big force encountered by the tree. What all this means is that the mass of the potato times its acceleration equals a huge force when it hits the tree. Bang!

Here is a question for science enthusiasts: If we make the cannon barrel longer, will the potato go farther? It seems logical that it would. If the barrel is longer, the ignited and expanding hairspray gas would push on the potato for a longer time. This should impart a greater force and make the potato go farther.

Sounds reasonable, right? So, what's the perfect barrel length? Well, that's for you to find out. A few experiments with barrels of varying lengths should provide the answer. Check out "Ideas for Further Study" at the back of this book for information on how an engineer would answer this question using the Scientific Method.

The third law says that when the potato is fired from the cannon muzzle, an equal and opposite reaction will be exerted on the support structure holding the cannon. This phenomenon is called "recoil" or "kickback." This is why it is important to secure the cannon to the launch platform.

Student Handout

Internal Combustion Engines: a Primer

photo courtesy of Daimler Chrysler, 2003 Jeep Grand Cherokee Engine

A Brief History

In 1867, 34-year old Nicolaus August Otto created an invention that changed the world. The German engineer developed the four-stroke cycle engine. Dubbed the Otto-cycle this invention remains one of the most common engines used in cars and trucks today.

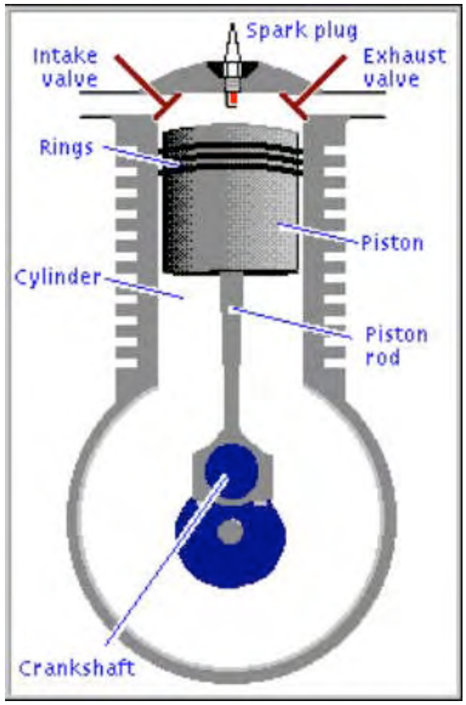
The Basics

The four-stroke engine is aptly named for it has four motions or "strokes". The four strokes of the internal combustion engine occur in the following order:

- Intake
- Compression
- Power
- Exhaust

This process is continually repeated, always in this sequence, during the operation of the engine.

The Internal Parts

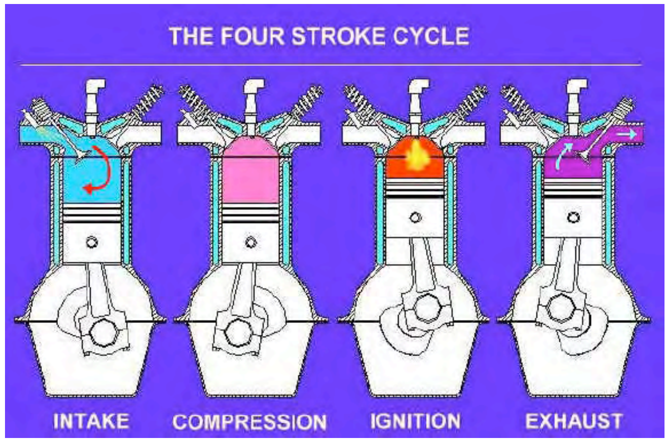


www.siu.edu/~autoclub/frange.html

Before explaining the operation of the four-stroke engine, some of the internal parts must be identified. Above is a drawing of the basic internal combustion engine. The description below is from *Back to the Basics: Fundamentals of the Four-Stroke Internal Combustion Engine* written by the Automotive Technology Organization at Southern Illinois University.

> The Intake Valve opens at a precise time to allow the air/fuel mixture to enter the cylinder. The Exhaust Valve opens at a precise time to allow the burned gases to leave the cylinder. The Spark Plug ignites the air/fuel mixture in the cylinder, which creates an explosion. The force of the explosion is transferred to the Piston. The piston travels up and down in a Reciprocation Motion. The force from the piston is then transferred to the Crankshaft through the Piston Rod (connecting rod). The piston rod converts the reciprocating motion of the piston, to the Rotating Motion of the crankshaft. The four engine strokes require two revolutions of the crankshaft to complete one full cycle.

The Cycle Explained



www.antonine-education.co.uk/physics_a2/options/Module_7/Topic_4/internal_combustion_engines.htm

Please refer to the above diagram to help describe each of the four engine strokes. Also, the following websites have excellent animated drawing of internal combustion engines that provide a graphic visual explanation of the cycle:

- www.siu.edu/~autoclub/frange.html
- www.howstuffworks.com/engine.htm
- www.keveney.com/Engines.html

The Intake Stroke
During this stroke, the piston starts at the top, the intake valve opens, and the piston moves down to let the engine take in a cylinder full of air and gasoline. Given that gasoline is a very energy dense chemical compound, only a small amount (a drop) of gasoline needs to be mixed with air for the cycle to work properly.

The Compression Stroke
The piston moves back up to compress the fuel / air mixture. As this happens, the intake valve closes and the exhaust valve is closed creating a sealed cylinder chamber. When this mixture is compressed, it increases in temperature, which in turn will make the explosion more powerful.

The Ignition Stroke
When the piston reaches the top of its' stroke, the spark plug emits an electric spark and ignites the gasoline. The gasoline / air mixture burns rapidly and the cylinder pressure increases. All of this pressure in the cylinder continues to increase until it explodes. The force of the explosion drives the piston down. As the piston moves downward, force is transmitted to the piston rod which is connected to the crankshaft. The crankshaft is rotated due to the force.

The Exhaust Stroke

Once the piston hits the bottom of the stroke, the exhaust valve opens. As the piston moves upward, it forces the burned gases out of the cylinder through the exhaust port (the tail pipe). When the piston reaches the top of its travel, the exhaust valve closes, and the intake valve opens. The crankshaft has now completed two full revolutions and the cycle is complete. The engine is ready for the intake stroke, so it intakes another charge of air and gasoline.

The above explanation is taken from two articles: *Back to the Basics: Fundamentals of the Four-Stroke Internal Combustion Engine* written by the Automotive Technology Organization at Southern Illinois University and *How Car Engines Work* written by Marshall Brain.

Parent Information Letter

Dear Parents / Guardians,

We at ___________school name here___________in ___________teacher's name here______class will be constructing and testing potato rockets on ________the {dates} here____________. We are conducting these experiments to learn about combustion. These lessons will be teacher led demonstrations with no hands'-on experimentation from the students. The students will play active roles by taking notes, developing hypotheses, and testing these hypotheses.

______The school name here_____________ is not responsible for acts the students may undertake outside of designated school times (put the times here).

Please sign this letter and return by (place a date here). By signing this letter you are agreeing to allow ________________________________ to participate in this class-level experiment.

Signed ____

Parent / Guardian of _______________________________________

Date ____